

SHIP PRODUCTION COMMITTEE  
FACILITIES AND ENVIRONMENTAL EFFECTS  
SURFACE PREPARATION AND COATINGS  
DESIGN/PRODUCTION INTEGRATION  
HUMAN RESOURCE INNOVATION  
MARINE INDUSTRY STANDARDS  
WELDING  
INDUSTRIAL ENGINEERING  
EDUCATION AND TRAINING

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# **THE NATIONAL SHIPBUILDING RESEARCH PROGRAM**

## **Proceedings of the REAPS Technical Symposium**

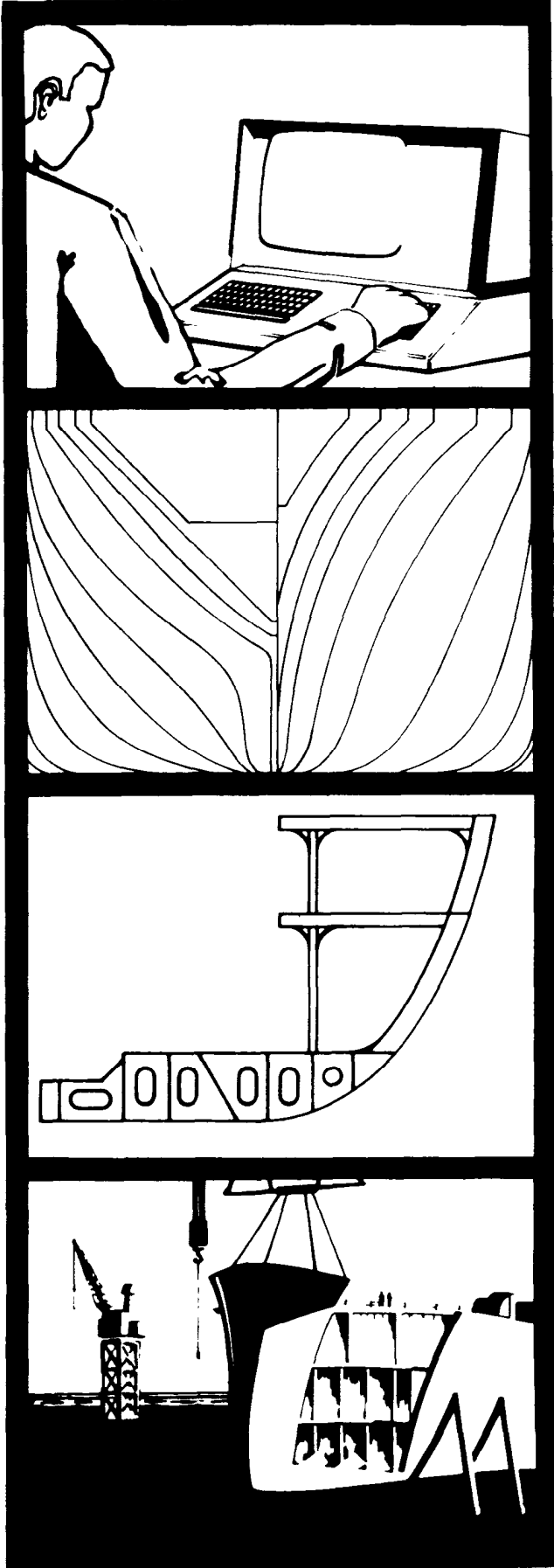
### **Paper No. 3: A Report on the IPAD National Symposium**

U.S. DEPARTMENT OF THE NAVY  
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NAVAL SURFACE WARFARE CENTER

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SHIPBUILDING

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## **A REPORT ON THE IPAD NATIONAL SYMPOSIUM**

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### **ABSTRACT**

**The Integrated Programs for Aerospace-Vehicle Design (IPAD) National Symposium was held September 17-19, 1980 in Denver, Colorado and was attended by some 420 people from the aerospace, computer, automotive and allied industries and agencies. The Symposium was sponsored by NASA and the IPAD Industry Technical Advisory Board.**

**In lieu of a summary of the presentations given at that conference, reproduced herein is the official IPAD Executive Summary, (Rev Sym A -- prepared under the auspices of Dr. Robert E. Fulton, IPAD Project Manager). A description of IPAD; its capabilities, perspective views by the engineering executive, manager, user and application programmer; and the IPAD development plan are presented.**

**Copies of the Proceedings of the IPAD National Symposium may be requested by writing:**

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## IPAD EXECUTIVE SUMMARY - D6-IPAD-70020-M

### 1.0 INTRODUCTION

The goal of IPAD is to increase U.S. aerospace industry productivity through the application of computers to manage engineering data in the 1980's. The system is being developed by The Boeing Company under contract to NASA. The system development is coordinated with the U.S. Air Force Integrated Computer-Aided Manufacturing (ICAM) and makes provision for interfacing design data with manufacturing organizations within a company, as well as with other companies. This document presents the purposes of IPAD, an overview of its capabilities, and how the system should be viewed by executives, managers, engineers, and programmers. It reflects IPAD as perceived at the software preliminary design stage and will be updated as IPAD development proceeds.

The purpose of the IPAD development is to define and implement an integrated computer software system to support planning, data definition, and control of an integrated engineering design process; storage definition and control of data bases containing large quantities of engineering data; and control and use of a large library of engineering application computer programs. Functional capabilities are provided and include: implementation of enhanced user interface features which support several levels of user skill; implementation of communication features which support distributed processing on several computing systems in wide use and implementation of state-of-the-art standard utilities for CAD and CAM in an integrated environment.

During the late 1960's the use of computers for integration of design data evolved as a basic concept. In the early 1970's a NASA-funded feasibility study (ref. 1 and 2) showed that increases in individual productivity are feasible through automation and computer support of routine information handling. Such automation will directly decrease cost and flowtime in the product design process and will improve the competitive position of the U.S. aerospace industry. The industry was deeply involved during the IPAD feasibility studies and continues to be involved in the current IPAD development. A description of this involvement is given in Appendix A.

The IPAD development plan, which is open-ended and evolutionary, stems from requirements (ref. 98 and 19) based on needed improvements in scientific data processing and from known potential improvements in engineering productivity (ref. 9 and 2). The development plan recognizes that IPAD is part of an environment composed of the IPAD system, users, technical application computer programs, and data bases. Thus the IPAD system is developed to be an intimate part of the total design environment.

## 2.0 IPAD DESCRIPTION

The IPAD system is a general purpose interactive computing system developed to support engineering design processes. Its primary function is to handle engineering data and management data associated with the design process. It is intended to support continuous design activities of a typical company mix of multiple development projects. IPAD serves management and engineering staffs at all levels of design (conceptual, preliminary, and final) and aids in the assembly and organization of design data for manufacturing processes.

The IPAD system design will support generation, storage and management of large quantities of data. Its capacity will only be limited by the hardware configurations selected by each company. The system is intended for use in a distributed computing environment having one or more central host computing systems and many remote computing systems. The number of terminals supported may range to several hundred and may be distributed across the host and remote systems. The IPAD software will function on the "third generation" computer complexes in use today by large aerospace corporations.

Figure 2.0-1 illustrates the relationship or the major software elements of IPAD. It is currently visualized as composed of four major software elements: 1) executive software to control user-directed processes through "interactive" interfaces with a large number of terminals in simultaneous use by engineering and management personnel and to provide communications between computer hardware within the IPAD distributed computing system; 2) a large number of utility software packages for routine information manipulation and display functions; 3) data management software (information processor) to provide a comprehensive, versatile capability for efficiently storing, tracking, protecting, and retrieving exceptionally large quantities of data maintained on multiple storage devices and 4) other systems interface software to provide communications to computing systems outside of IPAD.

Libraries within the data bases include the technical analysis and design computer programs utilized by various disciplinary specialists. Such programs are not part of IPAD, but must be provided by each company to form the complete design-software system. Some public technical programs will be included with the IPAD system to demonstrate its capabilities. The data base will include all official project information defining the characteristics of current baselines and alternative designs and their performance, as well as archival "handbook" information forming the technology base for company designs. Simultaneous access to the same baseline design information by all disciplinary

groups will thus be possible. Temporary storage, for design information being actively used by individuals or teams, will also be provided

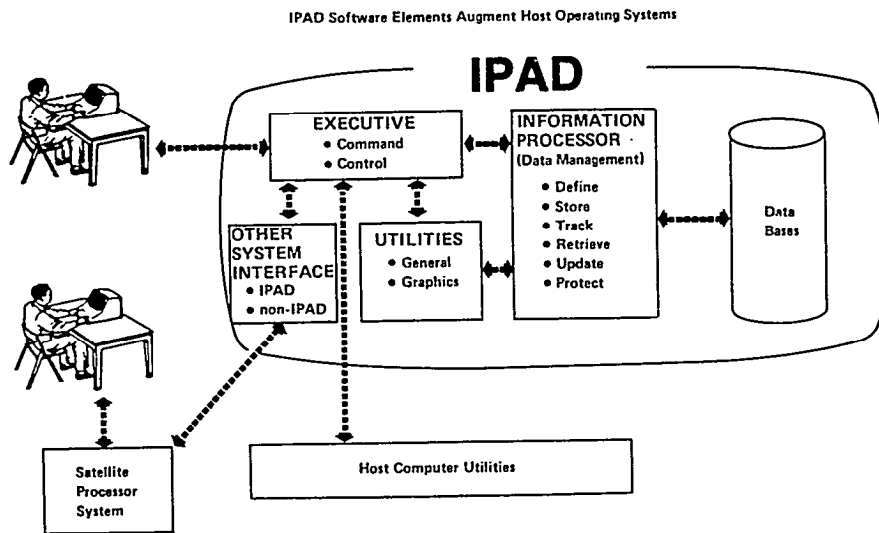


Figure 2 0-1 Primary IPAD Software Elements

IPAD is not a hands off "automated design" system and will not constrain company design methods. The characteristics and quality of aerospace designs in the future, as now, will depend on such elements as creativity of designers, quality of technical staffs and their analysis tools and design data, and coordination or design and manufacturing information. IPAD is a tool to improve the efficiency and effectiveness of these elements and to provide manufacturing direct access to engineering data. The manufacturing process is not encompassed by the IPAD system. However, there is a working agreement between the Air Force and NASA to insure compatibility between IPAD and ICAM. This capability will enable manufacturing users to take advantage of the design and data management features of IPAD in addition to accessing design information.

The IPAD system and its supporting documentation will be supplied to aerospace companies. IPAD may be installed by each company on its computers and used in a manner similar to the operating systems supplied with each computer. It will augment rather than replace the existing operating system. The IPAD system development plan provides for release of incremental capabilities implemented for CDC and IBM computing systems and allows a gradual transition from the current computing techniques to IPAD integrated techniques at a pace selected by each company for its own implementation schedule.

While IPAD is developed for use by the aerospace industry, it should support other complex processes such as large civil engineering projects, ship building, automotive design and the development of other computing systems. (See ref. 13 for examples of potential non-aerospace applications of IPAD.)

### 3.0 IPAD CAPABILITIES AND DOCUMENTATION

This section contains a brief description of the capabilities of the IPAD system and the documentation to be provided along with the IPAD system.

The IPAD system capabilities are:

- a) Manage data by means of a single-source, bank of current and historic information accessible to all users. Such a bank enables management to control and use data as a company resource and thus improve all of its operations by ensuring that all organizations have common access to a uniform information source which is continuously updated and purged of obsolete, redundant, or conflicting data.
- b) Provide computer aided planning of engineering design processes by a modeling method that makes it convenient to describe the design process as groups of related activities. This planning includes definition of computer based data interfaces which enable integrated information processing. These design activities may be time-phased as required to develop the technical definition of a product.
- c) Support computer aided design project management with the capability for defining design projects; assigning manpower, resources and schedule for tasks and subtasks; and for monitoring progress of design projects relative to resources and schedule.
- d) Support an open-ended computer program library of user-installed application programs in source and executable forms. One or more of these programs may be executed as an IPAD job. Each IPAD job will have sufficient library information installed with it to describe adequately the job's purpose and capabilities (abstract, key words, etc.). This information is available to anyone performing a function associated with the job and is used to plan and define process activities based on available IPAD jobs. This program library should minimize program redundancies.
- e) Enable users to interface effectively with the IPAD system by providing:
  - Fast, convenient access to the system and identification of individual users for security and control purposes

User-oriented, functional command language which guides the users control of the IPAD system

System prompting when users need online help.  
(Several skill levels are accommodated, such as expert, intermediate, and novice.)

Computer-aided instruction in the use of IPAD functions (this instructional system can also be used to train engineers in design procedures, use of computing tools, etc.)

Aid in locating input data, executing jobs, monitoring jobs in execution, and storing output data

Job status reports showing progress of the job and resources used

Aid to users in suspending jobs in execution and resuming execution under user control with minimum effort at a later time

'Aid to construct jobs from application programs in the IPAD program library

Aid to define data

f) Provide essential functional utilities including:

State-of-the-art graphics and interactive graphical capabilities for design drafting and finite element modeling

State-of-the-art programming aids for on-line programming, program maintenance, and installation of existing programs into the program library

Miscellaneous aids such as tutorial, text editing, menu building, report generation, and message processing

Documentation provided with the IPAD software include:

A reference design process (ref. 16) the interaction with manufacturing (ref. 17) and product program management systems (ref. 20). These serve as aids for each company's use in producing its unique version of the design process, information bank, and application program library

A software standards handbook to ensure consistent techniques for the IPAD system development and maintenance

IPAD user manual to provide reference material on IPAD functional capabilities

IPAD software workbooks to provide instructions on installation and maintenance of IPAD software

## 4.0 ENGINEERING EXECUTIVE'S (INDUSTRY) VIEW OF IPAD

IPAD might be viewed by industry as an advanced computing system for processing engineering data. The following are major considerations of the engineering executive's perception of IPAD.

### 4.1 EFFICIENCY

IPAD will provide the capability to increase productivity of a product design organization by providing tools for handling information. Examples of the reductions possible in one area of preliminary design (see Ref. 1, Vol. 7 for more detail) are illustrated by figures 4.1-1 and 4.1-2. These figures show flowtime and manhours required for one airplane configuration sizing design cycle in a stand alone environment and an integrated environment with data interfaces defined. The estimated reduction for the integrated environment are summarized as follows:

Flowtime is reduced to 30%

Man-weeks are reduced to 20%

### 4.2 COMMUNICATIONS

The IPAD interfaces with other systems will support communication between the computing systems within engineering and the computing systems of other functional organizations.

The IPAD data management capabilities will handle both business and scientific data types. These capabilities will support communications within engineering and between engineering and other organizations,

Figure 4.2-1 illustrates some of the engineering data types that may be stored and communicated with IPAD. Many organizations currently use commercial data base management systems (DBMS) to store and communicate engineering business type data such as release of engineering parts. Examples of business data are: part names, part numbers, part quantities, etc. Data of this type have characteristics and relationships that are easily communicated to people. In contrast engineering scientific type data are more complex and include elements such as coefficients of a polynomial expression and the geometric data defining the surface of an aircraft. These data have complex mathematical relationships and are handled by IPAD through an enhancement of current commercial data base technology to include both scientific and business data types in one integrated system.

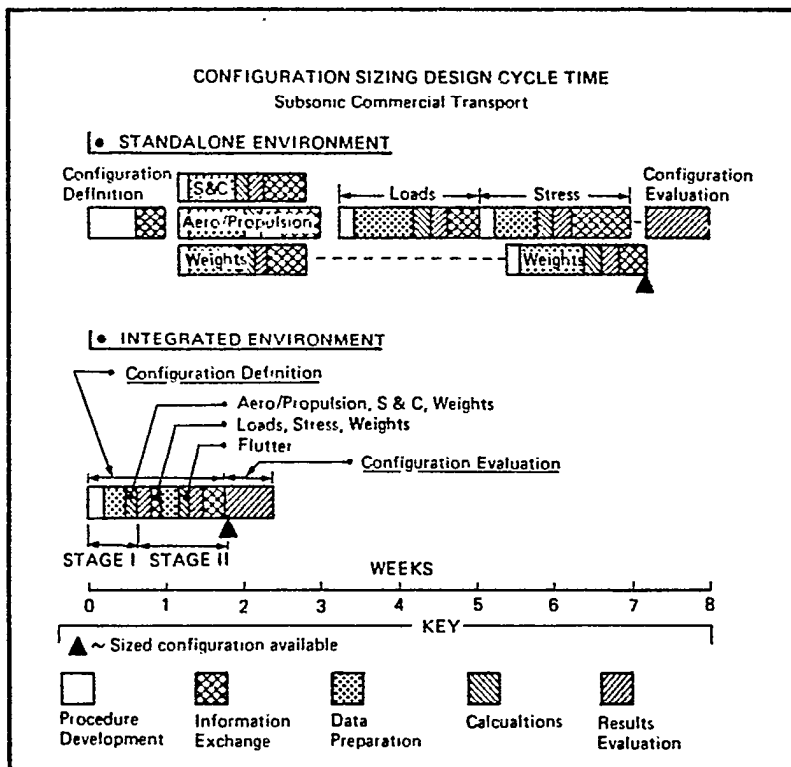


Figure 4.1-1 — Subsonic Transport, Relative Flowtime, Standalone/Integrated Environment

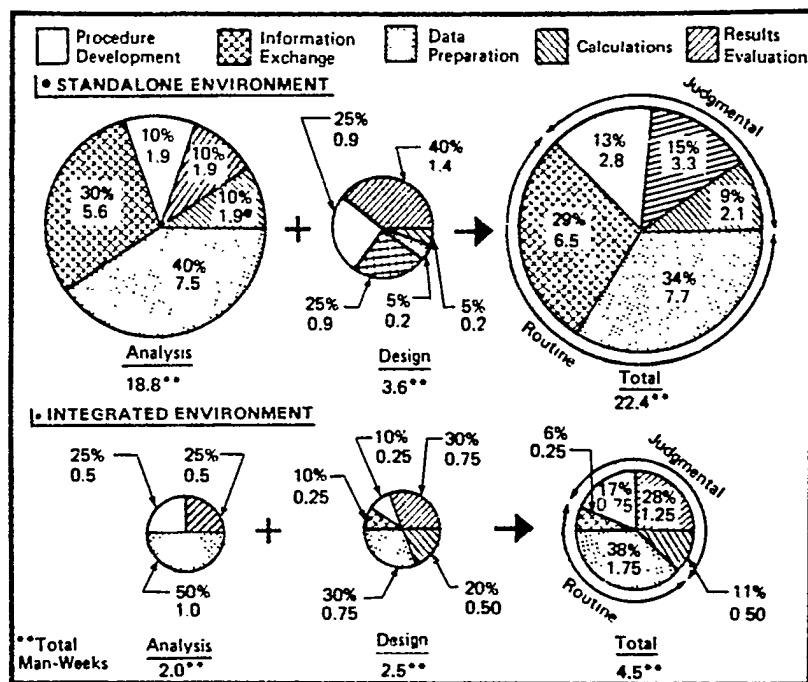
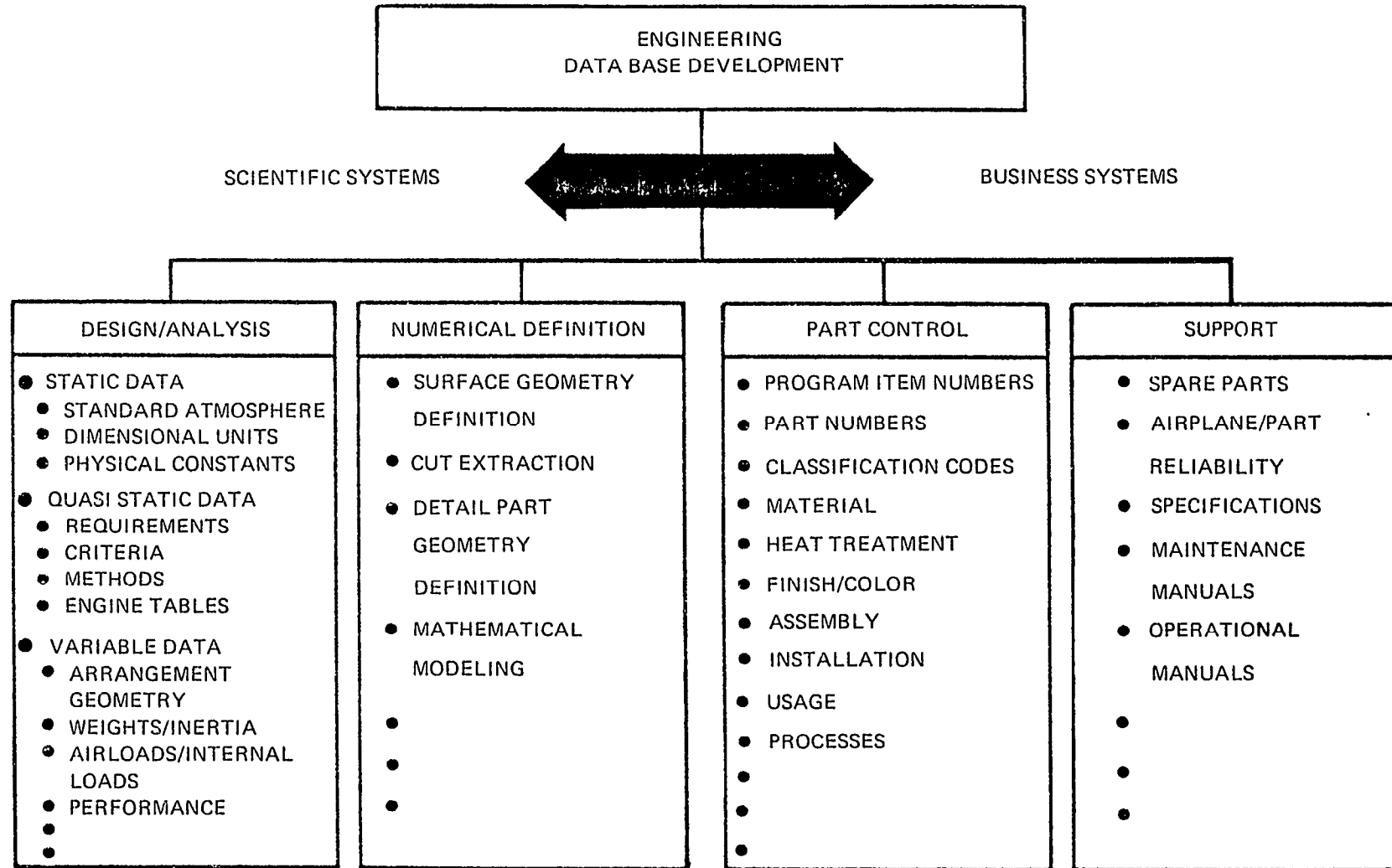


Figure 4.1-2 — Subsonic Transport, Division of Effort Standalone/Integrated Environment

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*Figure 4.2- 1. - Engineering Data Types*

Data interfaces within engineering are developed with the IPAD capability to plan design processes and define integrated data interfaces. These processes can be related to one another in a way that will cover the development cycle of a product from conceptual design through product certification and support. To maximize the benefits of IPAD, a coordinated effort is required on the part of engineering managers, group supervisors and methods research. The experience and quality of the personnel assigned to plan the process and define the required data interfaces will determine the effectiveness of the use of IPAD,

The IPAD capability to support definition of data interfaces can also be applied to the interfaces among engineering and other functional departments of a company, such as finance, marketing, and manufacturing. This can be accomplished through a coordinated effort initiated by department executives to utilize the capabilities of IPAD to plan and implements desired data communication among their respective organizations.

#### 4.3 APPROACH TO IPAD IMPLEMENTATION

The IPAD system is developed in the public domain and is available to the U.S. Industry. Incorporation of IPAD by a company may be planned as a transition, beginning with a small initial implementation for specific portions of the design process. This initial implementation can be built upon and expanded until all elements of the design process and its interfaces have been integrated. In this manner a company may implement IPAD at its own pace consistent with the benefits desired.

The cost of involvement in IPAD activities will be a function of how deeply each company elects to become involved and will remain under company control. A comprehensive approach for initial implementation and evaluation of IPAD could include the following tasks:

- a) Identity a team of specialists in each engineering discipline from ongoing design and analysis projects, methods research and the computing staff
- b) Review the reference design process model (D6-IPAD-70010-D), manufacturing interactions with the design proess (D6-IPAD-70011-D), and product program management systems (D6-IPAD-70035-D)
- c) Assess the applicability of the reference material to comparable functions within the company

- d) Select portions of the design process to be implemented and adapt the IPAD design process model to fit in-house procedures and standards
- e) Develop cost estimates and a schedule for initial implementation based on step d
- f) Initiate the IPAD program library by modifying existing application programs and developing new ones for effective integration based on the in-house IPAD design process models
- g) Initiate implementation of the IPAD information bank based on the data definition extracted from the in-house IPAD design process models
- h) Implement computer hardware/software configurations required
- i) Establish in-house procedures for maintenance of the IPAD system
- j) Utilize the computer aided instruction within IPAD to train engineering users
- k) Consider participating with other IPAD users to guide and shape continued development of IPAD

The cost of carrying out these tasks will depend on how comprehensive an activity is needed and how much has already been done. Steps b, c, d, and e could involve as much as 5 to 10 man years over a period of 4-12 months. Steps f, g, h, and i constitute initial implementation and the costs should be identified in step e. The conversion and installation of applicable computer programs and data into IPAD will be an ongoing process based on cost benefits. If possible, companies should consider a limited IPAD implementation for evaluation purposes in parallel with IPAD software development. Computer programs being developed or converted could be impacted by IPAD development issues and, similarly, the IPAD development itself could be influenced by the needs of such programs.

## 5.0 ENGINEERING MANAGER'S VIEW OF IPAD

IPAD might be viewed by an engineering manager as 1) a means to develop design processes which incorporate engineering computing tools and interface those tools based on data relationships, and 2) a means to plan and monitor the progress of design projects including schedules, resources and manpower assignments. Sample capabilities are described in this section.

### 5.1 DESIGN PROCESS SUPPORT

Design process networks are constructed with IPAD to integrate engineering activities and interface engineering data within engineering disciplines and between engineering disciplines. The basic building blocks for process definition are computer programs in the IPAD computer program library. These programs are the computing tools used by engineering and are executed as jobs. Jobs may be grouped and groups of jobs grouped to any level required to stage or phase the design process and to support forward and feedback communications.

Figure 5.1-1 illustrates an overview of the design levels which were used in reference 16 to describe the technical activities of the IPAD reference aerospace design process. Each level is further defined by one or more design networks of the type shown for IPAD level 11. This network establishes the Interfaces between engineering, marketing and finance and can be used to develop the design criteria for potential products.

IPAD will support displays of these process definitions and assist the engineer in the preparation for execution of the jobs required to accomplish activities identified in the process description. Engineers are assigned to accomplish these activities in accordance with the project plans described in 5.2.

### 5.2 DESIGN PROJECT MANAGEMENT

Computer aided design project management is provided by IPAD. Design projects are defined to control the execution of a complete process or any segmented portion of a process. The primary elements supported by IPAD are project planning and project records.

Tasks and subtasks are identified in a project plan. Each task is scheduled and resources allocated in the plan. Each subtask is scheduled and resources allocated in a task plan. A critical path may be constructed by defining dependencies of both tasks and subtasks. Tasks identify the work to be accomplished by engineering groups and subtasks describe the work activities to be

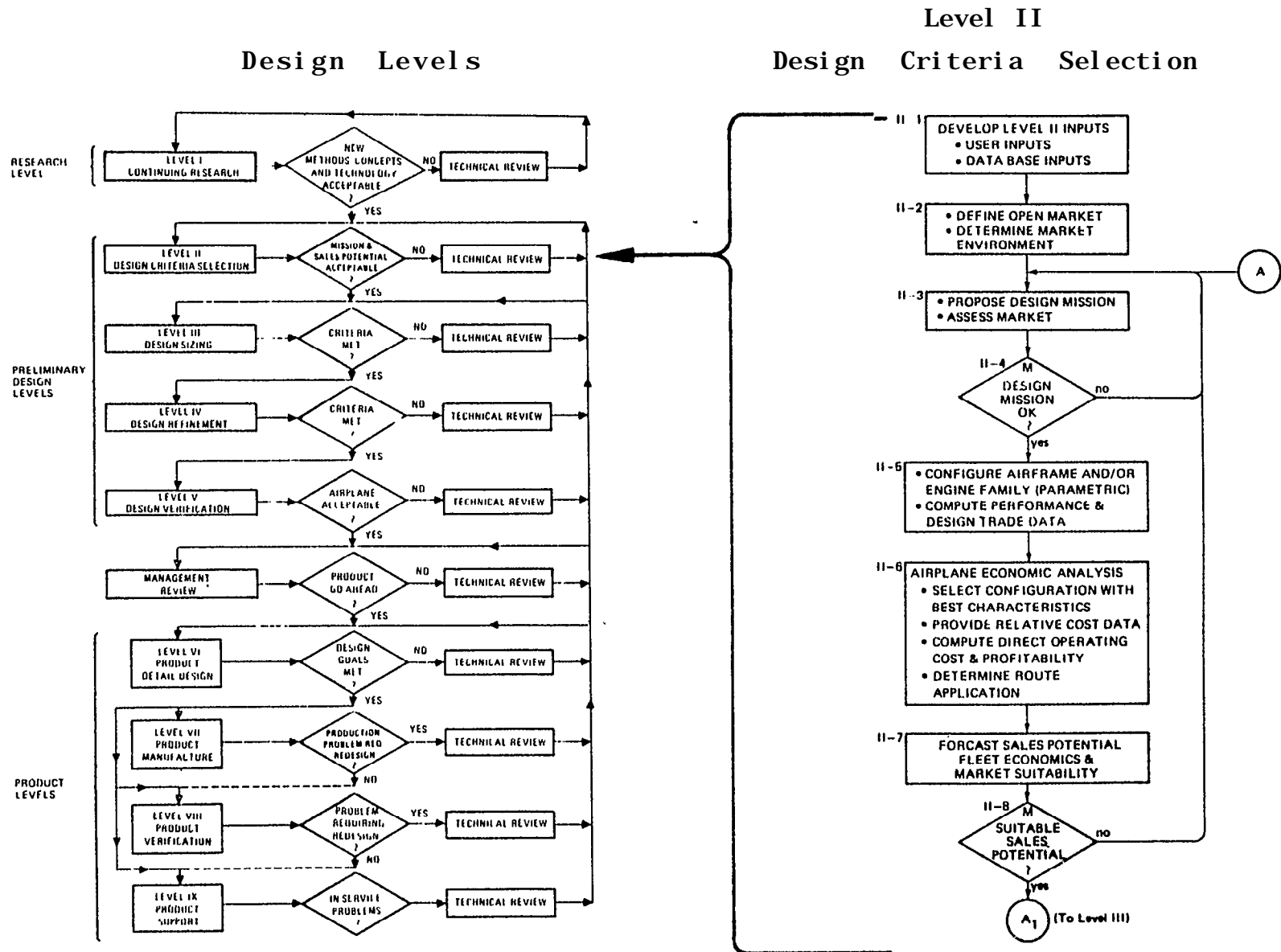


Figure 5.1-1. Reference Design Networks

accomplished by individual engineers. Each subtask may require execution of one or more jobs or IPAD utilities.

Project records are used as the primary means to identify the source and quality of all data generated and used by a project. These records are appended by IPAD to the data stored in the information bank.

IPAD will support interactive displays and automated pre-formatted displays of project records from the information bank. This will provide management with the capability to review plans, and schedules, make planned versus actual comparisons and track costs, such as development, production estimates, product support and product operation.

The engineering manager's decisions are based on known confidence in the data produced by a project. The known confidence stems from the process tools used and the planned quality of the input data used. These factors support risk evaluation by engineering managers of the technical definition of the product. The reduced time and resources for a design cycle permit the manager, based on known risk, to iterate these cycles until confidence in the quality and consistency of data is adequately established.

### 5.3 PERFORMANCE

Reduction of costs and schedules for design cycles were discussed in section 4.1. Managers can apply these improvements in costs and schedules to all applicable areas of their operation using a transitional implementation of the integrated information processing technology supported by IPAD. The reduction of routine data preparation by interfacing jobs with data stored in the IPAD information bank will shift the level of effort from routine to judgmental activities thus improving the quality of the solution. In addition, the number of job failures caused by errors in input data will be reduced. These factors will contribute to improved performance of each engineering unit.

## **6.0 ENGINEER'S VIEW OF IPAD**

**IPAD might be viewed by an engineer as an advanced interactive computing system tailored to the engineering users needs. These needs range from the random gathering of information to control of the execution of complex programs in the application program library and IPAD system standard utility library.**

### **6.1 DATA BASE SUPPORT**

**IPAD provides capabilities to store, retrieve and maintain engineering data. The IPAD information bank is a repository for historic data and data on current products and future products under development. Data maintenance provisions include version identification and the capability to track the differences between versions.**

**IPAD assists engineers in identifying and retrieving information. The engineer can request data by name or browse through the contents of the information bank by specific disciplines such as configuration design, wing design, loads, stress, hydraulic system, etc., or by key words such as wing aspect ratio, engine bypass ratio, cruise mach number, part number, etc. Ready access to engineering information is an important advantage for engineers, especially detail designers, and reduces the time to gather the information required to get ready for design work.**

### **6.2 IPAD APPLICATION PROGRAM LIBRARY**

**IPAD provides the engineering user with access to a company-wide application program library. These application programs are readily available for execution as jobs which are the state-of-the-art tools developed by each company to apply technology to its product lines. The engineer can request jobs by name or browse through the library by specific technology and by key words. This ready access to tools should enhance the engineer's technical capability and reduce duplicate development of programs.**

### **6.3 IPAD SYSTEM STANDARD UTILITY LIBRARY**

**IPAD provides the engineering designer with a set of standard utility programs which are state-of-the-art capabilities in such areas as graphics, design drafting, and finite element modeling. These utilities are supported by the IPAD system in a manner that provides a unified CAD/CAM capability in which a design may be created, analyzed, and released to the applicable manufacturing process within an integrated design environment. The geometry is**

stored in an IPAD standard geometry format and easily communicated among CAD/CAM applications and to the applicable manufacturing systems.

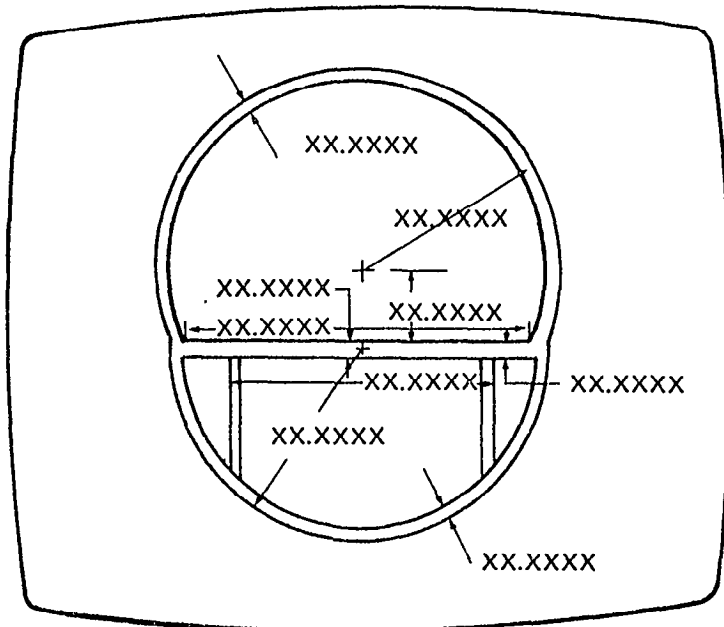
#### 6.4 WORK ENVIRONMENT

The engineer will work in an environment in which computing tools are readily available and structured to accommodate various user skills. Help is available on line and the engineer may easily terminate a session and resume at a later time. Most data bookkeeping is done automatically by the system, which can trace the origin of any data set.

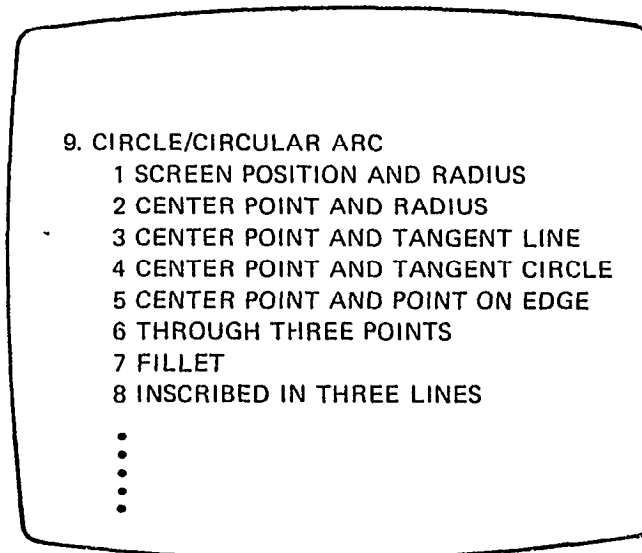
In the areas of creative design for which integrated processes may not be defined, the design drafting capability of the standard CAD/CAM utility will enable the user to construct, modify, display, and manipulate geometric definitions. These geometry definitions are used by manufacturing to support functions, such as tool path definitions. Figure 6.4-1 illustrates typical hardware supported by IPAD at a computer aided design work station. Menus may be displayed on the graphics terminal or on a slave text terminal as illustrated. Menu selection may be implemented with function buttons, with light pens or using a data tablet with a menu overlay. The system can access the product loft definition for both cut and surface extractions needed for detail parts. Retrieval may be accomplished rapidly in an interactive mode using a language comfortable to the user, such as:

"DISPLAY REAR VIEW WHERE BODY STATION = 960"

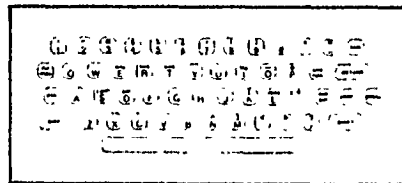
Computer program execution within IPAD is based on pre-defined job control and many data interfaces with the information bank can also be pre-defined. The user identifies the job to be executed and the project and subtask names. IPAD links the job to applicable existing input data sets based on the project name and the process data interface definition. The user inputs the required additional data and initiates interactive execution or submits the job for batch processing. In either case, IPAD will automatically store the user-supplied input and the output produced in a temporary private data storage area identified by the user's subtask name. The user may access the data by the subtask name and data set name. Computer-aided features for data validation such as set comparison and range checks will assist the user in evaluating the results. This improved data communication will reduce the time engineers spend on routine data preparation and result in increased time spent on judgmental activities.



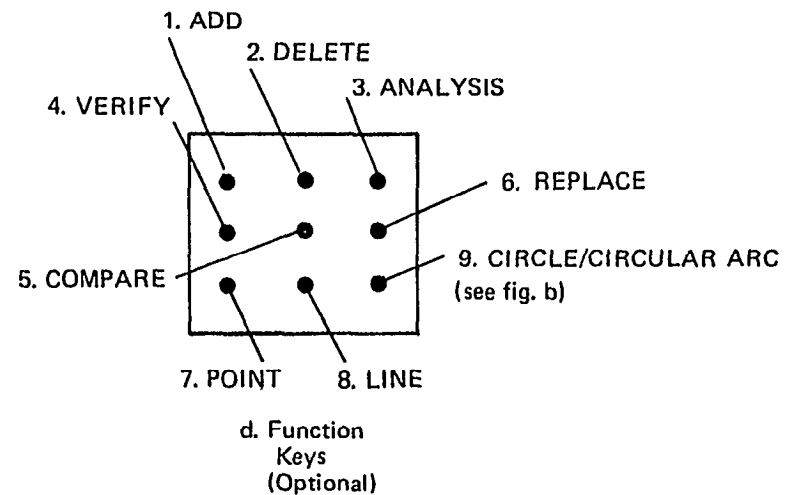
a. Primary Graphics Terminal



b. Text/Menu Terminal (Optional)



c. Keyboard



d. Function Keys (Optional)

Figure 6.4- 1. - Typical Equipment - CAD work station

The system will provide the capability for a user to manage use of computing resources such as central processor time. If resource limits are exceeded, the system will automatically suspend execution and package the completed results in a manner suitable for restart with minimum loss. The user may examine the results completed and resume execution. Status reports are available to each user for all subtasks in work. The status reports include such items as:

Subtask schedules

Computer resources budget/used/remaining by subtask

Jobs completed by subtask

Resources for each job

Jobs suspended and probable cause of suspension

Resources used for results completed prior to job suspension

Data sets created

Data sets due

IPAD provides a data release procedure equivalent to signing a drawing and may include categories such as prepared, checked, and approved. When the user is satisfied with the output, an appropriate entry is made by the user. After persons designated have checked and approved the data and made appropriate entries, the data is transferred logically by IPAD from temporary storage to permanent storage area and is accessible as released information. This relieves the engineering user from the burden of tracking data.

## 6.5 COMMUNICATIONS

Many features of the IPAD system will support both on-line and off-line communication between engineers. The terminal conference data viewing mode supports multiple terminals with common text and graphical displays. It will be possible to send messages on the screen and edit screen content from any of the terminals. Other online support includes review of process description and data interfaces. Offline output includes check print quality hard copies or complete drawings or screen content for coordination purposes prior to completion or release.

## 7.0 ENGINEERING APPLICATION PROGRAMMER'S VIEW OF IPAD

IPAD might be viewed by an engineering application programmer as a means to handle scientific data using a data base management system and to control application programs in a library environment similar to operating system and run time libraries thus simplifying use by the engineers.

### 7.1 PROGRAM DEVELOPMENT AND INSTALLATION

IPAD will support a large library of application programs and will provide the application programmer with a set of programming aids and standards.

Programs developed within IPAD or suitable existing programs may be installed in the IPAD program library which will support management of modules. Application programs must conform to an IPAD installation standard and will be installed as one or more operational modules. A job is use of a selected set of operational modules and/or other jobs executed by the user as part of a subtask. Any set of source code used several times will be entered once as a source language module and made available to the user community. The same applies to operational modules and jobs. Naming conventions result in unique names for all modules and jobs in the program library and are used as primary keys for program management. The construction of jobs from modules and the administrative information supported by IPAD is illustrated by figure 7.1-Y.

Programming aids are provided to support creation and maintenance of application programs and include on-line utilities for program text editing, debugging and update. In addition, host operating system programming aids may be accessed and used in conjunction with IPAD.

### 7.2 PROGRAM INTEGRATION

Program integration into IPAD involves linking programs as IPAD jobs to the data within the information bank and to other IPAD jobs as determined by its use within the design process,

Data formats must be defined for each input and output data set associated with a job. Two types of formats are provided. The first is for undefined data sets where IPAD manages data at the level of sets and does not know the contents of the set. The second is for defined data sets where data elements within a set and relationships between elements (i.e., structure of the data set) are defined and IPAD manages data at the level of elements,

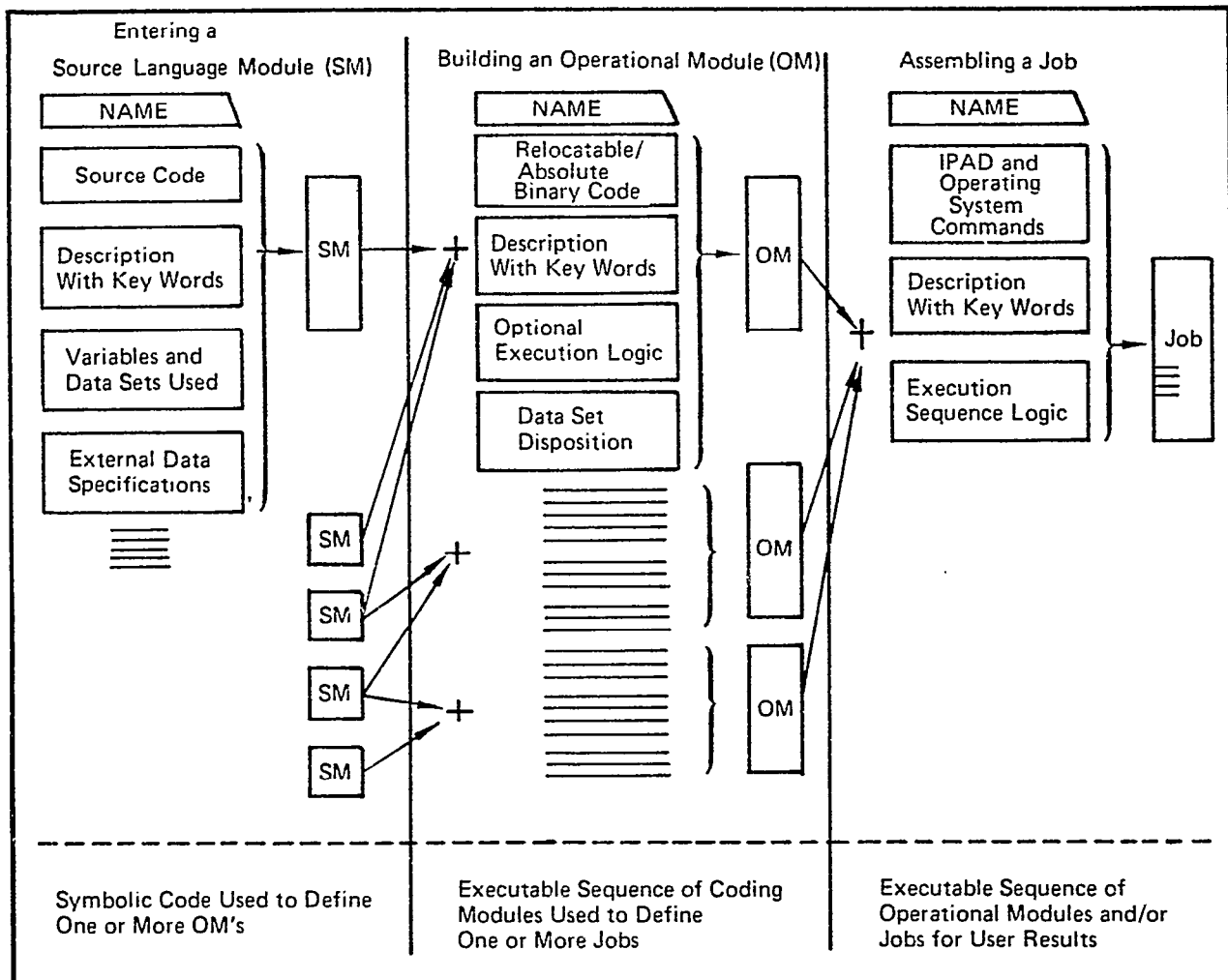


Figure 7.1-1 — Steps in Job Construction

A data modeling capability is used to establish definition of data flow within the design process. This definition identifies the source and destination of all input/output and makes provisions for job to job communication. Any required data reformatting or translation is identified by this data flow definition. Both forward and feedback data flow paths are supported. The source and destination definition are used to map storage and retrieval data flow between the process and the information bank and between related activities defined in the process.

### 7.3 PROGRAM MAINTENANCE

In addition to the programming aids mentioned in 7.1, the IPAD program library makes provision for version identification of modules and jobs and to track the difference between versions. The IPAD system itself is written in a high level system implementation language and has extensive system documentation. Sufficient information is provided to allow modification and enhancements to the IPAD system by individual companies choosing to tailor their IPAD installation.

## 8.0 IPAD DEVELOPMENT PLAN

The IPAD development is composed of two major steps.

1. Preparation of specifications and preliminary design of an IPAD system which will meet aerospace company design needs of the 1980's (ret. 16-21).
2. Design, code, document, test, and release a "First-Level" IPAD system, a truncated working version of IPAD, which encompasses the critical features and is extendable to a full IPAD system.

These steps are covered by the current development contract. Following development, it is NASA's intent (ref. 15) to turn over responsibility for IPAD maintenance and improvement to industry after an initial maintenance period of undetermined duration in which NASA and industry will share the responsibility. The exact mechanisms for cost sharing and the transfer will be worked out with industry before the end of the current development contract.

The first step developed specifications and preliminary design of the IPAD system based on functional and software requirements provided by NASA, as refined and expanded by the development contractor. Use has been made, where appropriate, of references 1 and 2. The IPAD functional requirements include support of the design process at all levels for long periods of time; information processing; technical computer program assembly, integration, and execution; sequencing of design tasks; and display of graphical and alphanumeric information. The interactive computer terminal is the primary interface between IPAD users and the system. The design of IPAD software builds on existing computer-aided design technology and uses new concepts in computer science where the need is critical. It will support today's design processes and permit development of new design methods for the future.

The second step develops First-Level IPAD from the IPAD preliminary design and meets minimum requirements specified by NASA. High levels of system reliability, maintainability, and portability are key characteristics of First-Level IPAD. First-Level IPAD includes incremental releases of selected software for testing by industry at regular intervals. The precise nature of software releases is determined during the development process. All First-Level IPAD software is developed for two time-shared computer complexes (CDC CYBER 172, and IBM 370) to demonstrate portability requirements which minimize machine dependency. A subcontract will be issued to substantiate the portability of the IPAD system and to demonstrate its usefulness to the aerospace

industry. Appendix D contains a brief description of the capabilities of each incremental release.

The IPAD system will be maintained by Boeing during the development contract. The major steps for development of IPAD are shown on figure 8.0-1. These are the primary events which industry may use to plan the transitional implementation of IPAD.

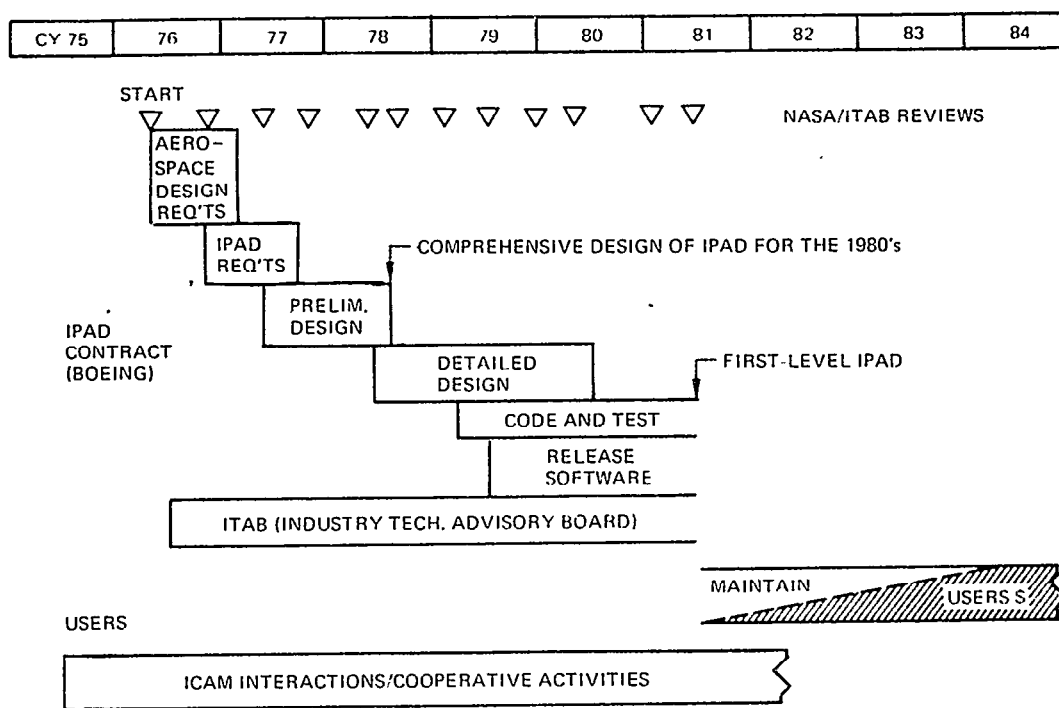


Figure 8 0-1 IPAD Development Schedule

## 9.0 FIRST-LEVEL IPAD PRODUCTS AND CAPABILITY

Based on the Industry Technical Advisory Board's prioritized needs and specific directions from NASA, First-Level IPAD was undertaken to implement a prototype engineering data management system suitable for distributed data base processing. The primary goal was to establish proof of concepts of the multischema architecture for an engineering data base management system. In addition, network communications capability was to be developed that would emphasize data communications and support system demonstrations. The initial host development computers for First-Level software are a CDC CYBLR 720/NOS and a DEC VAX 11/780, and *planning is underway* for migration to an IDM/VM/CMS computer complex.

### 9.1 PRODUCTS AND CAPABILITIES

Early development of First-Level IPAD included some experimental and prototype software products, Relational Information Manager (RIM) (ret. 29) and the IPAD integration prototype, (ref. 23). The primary products of First-Level IPAD include data management, network, geometry, graphics, and limited user interface software. In addition, engineering applications and demonstrations will be developed and delivered with the system

Data management is primarily a CDC host function and is carried out by the IPAD Information Processor (IPIP). The IPIP capabilities include data definition, data manipulation by application programs and ad hoc user queries. The data definition facility allows for network, hierarchical and relational data structures, separately or in combination. In addition, a data set ownership facility allows a user separation and control of his own data. Geometric data has been given special attention and the system supports specialized geometric primitives and a geometric processing. The data management system is designed for distributed data management and will also support distributed processing. The distributed data management capability will include support of integrated and interfaced programs executing on the DEC host requesting data from or sending data to the data manager on the CDC host. Real time queries on the DEC host are possible.

The network software supports high-speed communications between a CDC host and a DEC host using Network Systems hyperchannel hardware to achieve 50-million-bit-per-second communications capability. The network software provides data communication between the two hosts, supports execution of application programs on either host from either host, and provides

access to the data management capabilities on the CDC host from user requests on the DEC host.

The geometry, graphic, and user interface capabilities are divided between IPAD functions on the DEC and CDC computers. The DEC functions primarily support the geometry aspects of design creation and provide for pre- and postprocessors associated with the design drafting capability of AD-2000 (ref. 28). The CDC host functions supporting this capability are the standard graphics display utilities, the General Purpose Graphics System (GPGS-F) (ref. 25). In addition, the CYBER function to support geometric transformations is being developed to address the trend towards an ANI standard (ref. 26).

The IPAD applications and demonstrations cover a broad spectrum of engineering activities. The demonstrations utilize both the CDC and the DEC computers and cover areas of analysis, design, project management, and the interaction of design with manufacturing. Goals for increased engineering effectiveness in an IPAD environment are being established with ITAB support. During demonstrations, data will be gathered and compared with these goals.

Figure 9.1-1 illustrates the variety of IPAD applications that will be the substance of the demonstrations. This matrix shows the particular Functions within First-Level IPAD and the application programs to be developed to support the IPAD demonstrations. The matrix also illustrates the First-Level developments as contrasted with the probable future Second-Level and Third-Level developments.

## 9.2 MIGRATION OF FIRST-LEVEL CAPABILITY TO IBM COMPUTER COMPLEX

Plans are to begin, in 19817, the migration of the First-Level software products from the CDC/DEC host environment to include an IBM host complex. Associated with this migration would be an appropriate set of applications and demonstrations, similar in character to those for the CDC/DEC equipment. These demonstrations will be conducted to show the versatility and portability of the IPAD software.

## 9.3 MANUFACTURING DATA BASE MANAGEMENT SYSTEM REQUIREMENTS

A preliminary document (ref. 24) describes the data base management requirements of the manufacturing process. This document utilizes the work on the sheet metal wedge from the ICAM program (ref. 27) and traces the process of manufacturing of a sheet metal part and as well as its interaction with the design process. This work provides an initial assessment of the potential of IPAD software in supporting manufacturing activities

and helps define where IPAD enhancements are needed, This activity is closely coordinated with work on CAM data management requirements carried out under the ICAM program

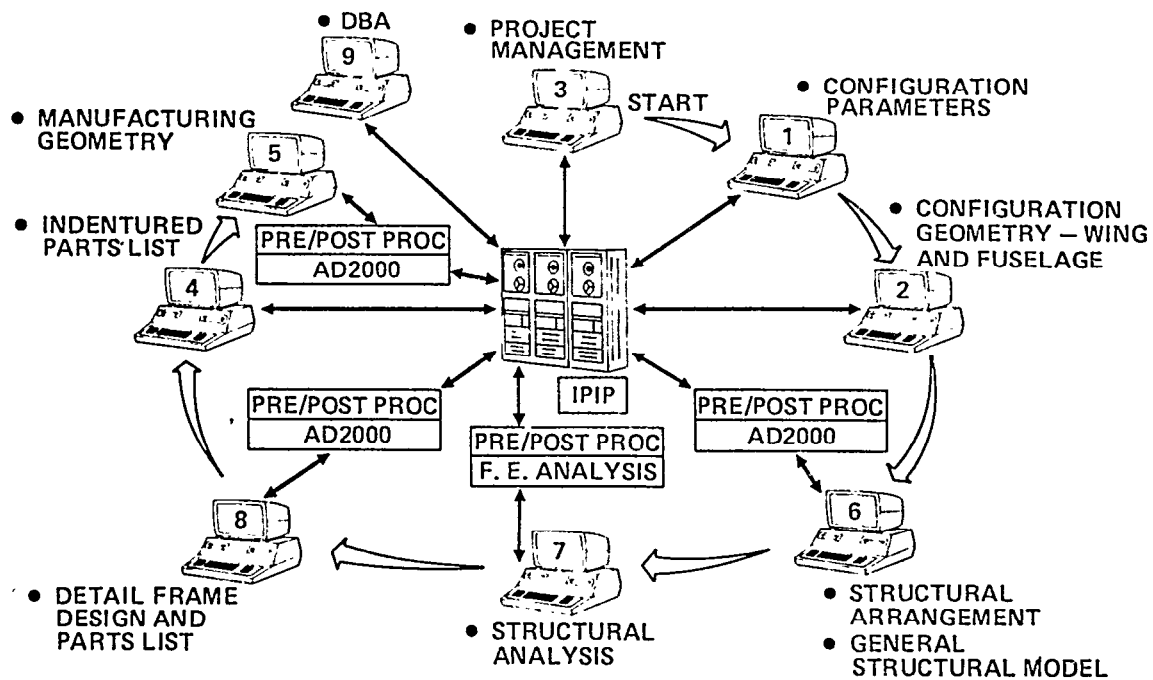


Figure 9.1-1 First-Level IPAD Integrated Demo

## 10.0 EXTENSIONS TO FIRST-LEVEL SOFTWARE (SECOND-LEVEL IPAD) PRELIMINARY DIRECTIONS

Considerations are underway to improve the performance and extend the capabilities of First-Level IPAD to produce Second-Level IPAD software and technology which will be more useful to engineers in a product development environment. The following capability extensions are under consideration and have been prioritized by ITAB in order of high to low priority. Decisions on specific capabilities to be developed will be made following appropriate NASA and industry review, as well as through consideration of manufacturing needs identified through cooperative efforts with the ICAM program.

### 10.1 HIGH LEVEL DATA MANAGEMENT

This package would provide capabilities for easy organization, control, and use of all required kinds of data in a large, integrated production engineering environment. The capabilities for establishing an information bank supporting hierarchical ownership and control of data would be provided. The capabilities would be suitable for storing of data developed and used by a large engineering organization involved in the detailed design of a production aircraft. Organization of data should provide hierarchical structuring in successively smaller blocks, with ownership established at each node in the tree. Control of data should provide an owner with rules, standards, access, update, and version control for all or selected parts of the data under individual ownership. Engineering data (including that contained in engineering drawings and information used in engineering/manufacturing interactions) must be supported.

### 10.2 DATA PROTECTION AND SECURITY

This package would provide capabilities for reliability, security, restart, and recovery. Second-Level IPAD should be suitable for production usage and comply with company proprietary data handling requirements. No special provision would be made for classified information except that it will be possible to use physical isolation for processing such information. Second-Level IPAD would (1) have facilities for keeping records of data accesses, (2) enforce appropriate user identification, (3) meet system reliability requirements (both hardware and software), and (4) make adequate provision for journaling, backup, and recovery.

### 10.3 DISTRIBUTED FUNCTIONALITY AND USER INTERFACE

This package would provide a uniform and user-friendly user interface, including capabilities for transparency of functionality. A uniform, transparent user interface would be provided that would foster the use of Second-Level IPAD in a production engineering environment. A common user-oriented command language would be provided for all hosts. IPAD functions would be distributed in a fashion transparent to the user, and a facility provided to make possible the integration of applications, the locations of which are transparent to the user.

### 10.4 PROJECT MANAGEMENT SUPPORT

This package would provide capabilities for support of engineering management, including project planning and monitoring. These capabilities would include facilities to store, control, and use planning data, such as resources and milestones, as well as performance data relative to the plans. To integrate the management and the engineering performance functions, the engineering data would be related to the management data, and release of engineering data would automatically trigger recording of milestone completion. Conversely, the planning data could be evaluated against the engineering data to notify management and the responsible engineers of upcoming milestones or to give a history of schedule performance.

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ITAB

NASA-IP0

## APPENDIX A

### INDUSTRY INVOLVEMENT IN IPAD SYSTEM DEVELOPMENT

#### BACKGROUND

The definition of IPAD has evolved over many years from a study and critique process that included extensive aerospace industry involvement. Two in-depth studies of the feasibility and possible forms of an IPAD system were carried out by the Boeing Company and General Dynamics/Convair (see refs. 1 and 2). The total cost of these studies over a 17-month period was \$611,000. Each study contractor undertook a careful dissection of the vehicle design process to delineate those functions and tasks that can be beneficially supported by computer hardware and software and then defined the format and elements of a software system that could substantially improve the design process. They also assessed the impact of this IPAD system on company computer hardware requirements and on the performance of company staffs and evaluated its cost and benefit potential.

One company examined these questions in the context of design of three kinds of vehicles--a large subsonic transport, a supersonic transport, and a hydrofoil--and developed a comprehensive, detailed picture of the design process as a multilayered network of functions. The other examined intensively the tasks and interfaces of individual designers and groups and analyzed carefully the information flow in design. They considered the effects of the detailed constituent parts of the design process and extrapolated their experience with existing software systems to arrive at computer requirements, costs, and benefits of IPAD software. Both concluded that IPAD is feasible and will fit on existing computers. They arrived at software systems that differed in detail, but exhibited the same general characteristics and order-of-magnitude costs. Projected benefits included 25-90 percent time and 20-60 percent cost savings in design, better management visibility, and reduced risk and cost resulting from greater depth in early trade-offs, on-time designs, and fewer design changes during production.

Results of these studies were presented in four oral reports that were well attended by representatives of industry; for example, 83 industry representatives attended the final oral presentations. Following completion of the studies, the results were critiqued by teams from McDonnell Aircraft Co.; Lockheed-Georgia Co.; Grumman Aerospace Corp.; Rockwell International corp., Los Angeles Aircraft Div.; Control Data Corp.; IBM Corp.; and Sperry Univac. These firms examined such questions as completeness of the studies, credibility of the proposed systems and projected development parameters, user acceptance, and government and industry roles. They expended significant effort

over four months, employing 31 team members and about 100 part-time consultants. The critique reports (refs. 3-10) reveal a wide spectrum of views, but strong consensus that IPAD development should proceed, should not include technical module development which should remain largely the prerogative of industry, and should provide early delivery of software and user involvement. Because of the inevitable budget limitations, it was recommended that NASA limit its specific objective to production of a truncated, but "working". system.

Other evaluations of IPAD include an Army-funded study by McDonnell Douglas Astronautics Co. of its benefit potential for missile design (ref. 11) and a small NASA-funded study by Battelle Columbus Laboratories of its potential for non-aerospace application (Ref. 13). In addition, the NASA Research and Technology Advisory Committee (RTAC) on Materials and Structures sponsored a colloquium of high-level aerospace managers at MIT on January 30-31, 1974, at which IPAD was examined and discussed (ref. 12). NASA published an IPAD "Prospectus" in February 1975, which set forth the plan for development, initial maintenance, and release of IPAD; for an Industry Technical Advisory Board (ITAB) to advise the IPAD contractor, and for a user-controlled organization to accept maintenance responsibility for IPAD software. NASA then conducted a survey of 41 aerospace companies seeking their commitment to become a member of ITAB during IPAD development; to evaluate IPAD software before it is generally released; and to financially support, in the context of a user-controlled organization, maintenance and improvement of IPAD software after its value to their company had been demonstrated. A summary of the responses is given in the attached table (Figure A-1) according to company categories. Two messages of a general nature were apparent in the responses. First, support for the IPAD concept and willingness to provide advice and counsel through the ITAB was very good from the large and medium airframe companies for whom IPAD would be primarily tailored. Second, most companies prudently preferred to defer hard commitments beyond ITAB participation until they had a chance to assess results. A few companies specifically declined commitments to participate in the IPAD project, and these fell in two categories; either IPAD did not appear to meet needs of their particular design process; or they saw IPAD aimed at design problems larger than their company activity. Several such companies wished to remain informed on IPAD progress with an opportunity to re-evaluate their position later.

Company	Letters		ITAB Member?				Eval. Software?				Support User GP?			
	Sent	Replies	Yes	EL	NS	No	Yes	EL	NS	No	Yes	EL	NS	No
Major Airframe <sup>1</sup>	15	15*	15				4	9	2		1	10	4	
Medium Airframe	6	5	4			1			4	1	2		2	1
Light Airframe	5	4		1		3		1		3		1		3
Helicopter	4	4	2	1		1		2	2			2	2	
Engine <sup>2</sup>	5	5*	3			2	2	1		2		3		2
Other	2	2		1		1		1		1		1		1
Computer	4	4	2		1	1	1	1	1	1	1	1	1	1
	41	39	26	3	1	9	7	15	9	8	4	18	9	8

<sup>1</sup>represents 6 corporations

<sup>2</sup>represents 4 corporations

EL Evaluate position later

NS Not specific

\* Some replies provided by other companies in a corporation or through a corporate reply

*Figure A-1 Industry Response To IPAD Prospectus*

## CURRENT INVOLVEMENT

The Industry Technical Advisory Board (ITAB) was formed by the development contractor soon after contract initiation to afford industry the maximum opportunity for influencing the course of IPAD development. ITAD consists of members and observers representing major U.S. aerospace and computer companies, and meets periodically. The ITAB structure is illustrated by Figure A-2. ITAB activities include review of planning and technical documents, critique of key development decisions, ranking of IPAD requirements, identification or demonstration programs, and consideration of the formation of an IPAD user group.

# INDUSTRY TECHNICAL ADVISORY BOARD (ITAB)

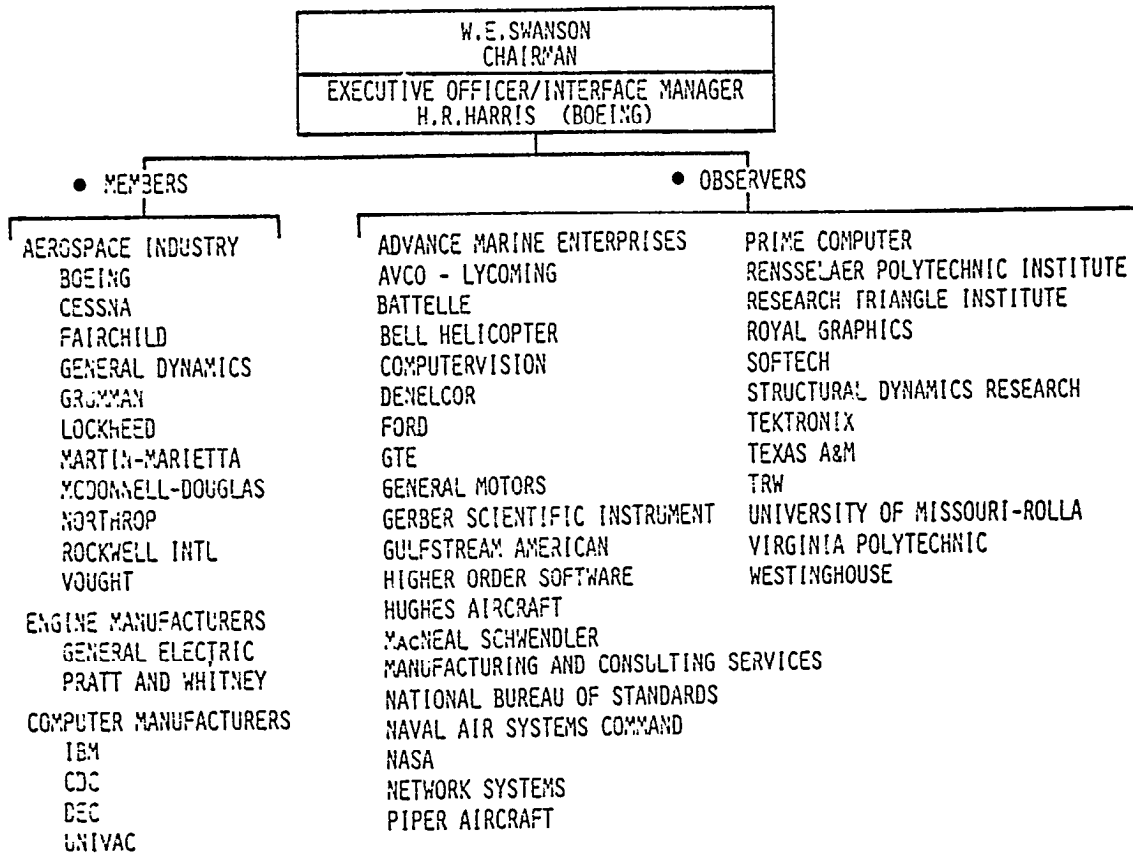


Figure A-2 Industry Technical Advisory Board (ITAB)

## APPENDIX B

### IPAD DEVELOPMENT PHILOSOPHY

The IPAD development philosophy is to produce a user oriented interactive system with portability as a design objective. The system design makes provisions for extending its capability as an open-ended evolutionary process having minimum impact on users of the system. The following are major considerations supporting this development philosophy.

A systematic software development process is used consisting of the following principal steps:

- User specification of requirements (ref. 18 and 19)

- Analysis of user requirements (ref. 22)

- System preliminary design (ref. 21)

- System detail design

- System coding

- system development tests

- System acceptance tests

- System installation/maintenance

Each step is documented completely to provide continuity of system development. The requirements have been developed to encompass the entire engineering design process, its interface with other organizations and user needs. These requirements are being used to produce the preliminary design of a "Full" IPAD system. The cost and time to develop individual IPAD system modules, a priority ranking of the requirements, and a definition of the basic IPAD software components will be used to identify the "First Level" IPAD system within the constraints of the contracted funds available. The "First Level" IPAD is a subset of "Full" IPAD and will be capable of extension to "Full" IPAD.

Since the IPAD development is long term, incremental releases have been planned. Preliminary design will be completed for "Full" IPAD and the remaining steps--detail design through user training--will be done for "First Level" IPAD for each incremental release on two host computing systems.

The IPAD development is driven by the requirement to produce an effective interactive user oriented system. This requirement

is addressed by developing models of the user interface and other systems interface as part of IPAD preliminary design. These models are used for walk through scenarios posed by engineers to test the primary functional requirements of the IPAD system. The tests further substantiate the computing staff's understanding of the requirements and help formulate the language syntax that IPAD will display during terminal operations.

Modular development will be used throughout IPAD to improve visibility of functional elements of the IPAD system and to facilitate testing and implementation. Machine dependencies will be minimized and isolated within interface modules wherever practical. Other advantages of developing a modular system include: improved ability to deactivate optional functions, ease in isolating changes to the system, and ease of installation of new functional modules.

IPAD will be implemented in a high level system implementation language for two major computing systems to make its initial use available to many companies and to test the capability to transfer the system from one host to another.

The acceptance testing conducted by the IPAD engineering development team will include execution of typical application programs based on scenarios developed to demonstrate the usefulness of IPAD. These application programs are obtained from or released to the public domain and will be delivered with IPAD to provide an initial technical capability which demonstrates functional capabilities of IPAD.

## APPENDIX C

### KEY SPECIFICATIONS

This appendix contains a summary of key IPAD specifications relative to performance of the Full IPAD system,

#### HARDWARE CONFIGURATIONS

The IPAD system shall support processing on computer hardware complexes supplied and maintained by each company incorporating the IPAD system. IPAD shall be Capable of distribution over multiple processors or of operating on a single processor. In addition, other computing systems can be interfaced to IPAD as satellite computing systems. The following ranges of hardware configurations shall be possible:

- 1-4 large scale computer systems

- 0-100 remote satellite computer systems

- 100-800 interactive terminals (approximately 25% will be used in graphical mode and 75% in text mode).

As a minimum, the IPAD system shall be compatible with the following computing systems:

- CDC CYBER 170 Series

- IBM 370 Series

- DEC PDP 11/70

#### SIZE OF DATA BASE

The data volumes and data processing activities that IPAD supports vary from company to company. The following guidelines establish the upper bound on data volumes.

Two product development processes through detail design are in progress at any given time. The data storage required is:

- Immediate access - 150 billion bits

- Archive (10 min. access] - 190 billion bits

- Archive (24 hr. access} - 360 billion bits

Ten products are undergoing sustaining design. For this activity, it is assumed that 20% of the total sustaining design data is required for current work and requires immediate access; 40% consists of archived drawings which must be available within 10 minutes; and the remaining 40% is also archived and must be available within 24 hours. The data storage required is:

Immediate access - 470 billion bits

Archive (10 min. access) - 940 billion bits

Archive (24 hr. access) - 940 billion bits

Preliminary design, of exploratory nature of 10 products per year. Data storage required:

Immediate access - 100 billion bits

Archive (24 hr. access) - 620 billion bits

For archival purposes, it is assumed that there is a continued increase of data volume that corresponds to one product description (detailed design) every two years and 10% of the information developed during exploratory preliminary design. The annual increase in data storage is:

Archive (24 hr. access) - 310 billion bits

The bounds of data storage required are as follows (the lower bound is assumed to be approximately 10% of the upper bound):

	Lower Bound	Upper Bound	Annual Growth
Immediate access (billion bits)	70	720	
Archive - 10 min. access (billion bits)	310	1130	
Archive - 24 hr. access (billion bits)	190	1920	310

## RESPONSE

The IPAD system monitors response time and controls access to the system when response time is above a parameter set by each company using IPAD. Response time is defined as the time elapsed between the last input by the user and the first character displayed by the computer. The response times given are those for

which the user will be comfortable and continue to utilize the terminal for his purposes. The following are design goals:

(15 to 60 seconds)

Access functions where the user is familiar with the delay.

Single enquiries where the user is familiar with the delay, cued by a message from the computer within two seconds acknowledging the command.

System failures and recoveries, cued, where possible, by a message from the computer within two seconds warning of the delay.

Loading of programs and data for execution and processing, cued by a message within two seconds acknowledging the command.

Restart from a prior session.

(4 to 15 seconds)

Low key enquiry dialogue possible but awkward.

Intense creative dialogue not possible.

(2 to 4 seconds}

Complex enquiries where continuity of thought is necessary.

Initial acknowledgment by the system that it is "listening."

Error messages.

(Less than 2 seconds)

Intense creative dialog.

Acknowledgment by the system that a command has been received.

Response to a paging request through a keyboard.

(Less than 1 second)

Response to a paging request using a light pen.

Development of geometric entities.

(Less than 0.1 seconds)

Brightening of characters from a light pen selection.

Appearance of a line when using the light pen as a drawing stylus.

Appearance of a character from a CRT keyboard input.

The critical threshold for effective creative dialogue is two seconds. Beyond two seconds mental efficiency degrades rapidly and delays beyond fifteen seconds are structured to relieve the user of both mental and physical captivity (see ref. 1, vol. 4).

## ACCURACY

The system accuracy will be to store numerical data with at least 10 significant digits and to perform arithmetic operations with no additional loss of accuracy other than that imposed by purely mathematical considerations and the characteristics of arithmetic operations of the host computing system.

## EFFICIENCY

At all times the active system configuration will be structured on a minimum system functional support consistent with the user needs. The responsibility for efficient operation is a system design requirement and the user is not required to guide the system into its most cost effective support.

## RELIABILITY

During any consecutive four week period, the minimum average user availability for the IPAD system is not less than 97.5% of the total available host computing time allocated to IPAD. The IPAD system is considered available when a user is able to productively perform his desired objectives.

## TRANSPORTABILITY

The system design shall be as machine-independent as possible and its operation shall be demonstrated on CDC and IBM computers. It is intended that the system will be used on other existing computing systems and be adaptable to future computing systems.

APPENDIX D  
DESCRIPTION OF INCREMENTAL RELEASES

IPAD INTEGRATION PROTOTYPE SOFTWARE-- RELEASE 0.0

The first release of IPAD software was made in October 1979, It consists of the prototype information management system, (RIM) an integration package, CDC/DEC communications software based on the Hyperchannel link, and various other software packages available for IPAD use and distribution and which have been integrated within the prototype. It permits IPAD users to create geometry on the DEC host, transmit this geometry over the high-speed network to the CDC host where it is inserted into the IPAD prototype data base, and finally to Connect the geometric model to a finite element model and execute ATLAS and SPAR programs- Query and display capabilities of the results are available with this package, The specific software available under this release is:

IPAD Integration Prototype System

- Prototype GRTS (RG Library)
- Patch II Display (RD Library)
- Patch II User Interface (RU Library)
- IPAD Integration Prototype
  - AD-2000 Postprocessor to RIM
  - Finite Element Modeler
  - Preprocessor to ATLAS and SPAR
  - Postprocessor to ATLAS

RIM II (Relational Information Manager)

GPGS-F (A Graphical Display System)

Design Drafting Pre/Postprocessor (AD-2000 PDP 11/70 IAS)

Pascal Compiler

CDC/DEC Communications package

SPAR (Finite Element Program)

ATLAS (Finite Element Program)

FIRST-LEVEL IPAD, RELEASES 1.0-3.0

These are incremental releases of First-Level IPAD software, each building upon the previous release, Release 1.0 provides the fundamental data management capabilities and the internal

communications facility for the CYBER. It can be used to demonstrate fundamental data processing capabilities of IPIP and make an assessment of its performance characteristics. In Release 2.0, the data definition and manipulation facilities of the data manager are added. Release 3.0 adds the query processor, the IPIP geometry processing capabilities, VAX based capabilities, the interhost communications, remaining executive services (including performance measurement), and IPIP support for ANSI geometry transformations and CODASYL set processing..

A more detailed description of the functionality of these releases in relation to the functional architecture of First-Level IPAD is contained in the following,

### First-Level IPAD Functional Architecture

A hierarchical breakdown of First-Level IPAD functional capability is contained in figure D-1.

#### IPAD Information Processor, IPIP

IPIP contains two main functional subcomponents, the data manager and language interfaces. The data manager provides all data processing capabilities including multiuser threading, mapping, binding and physical storage and retrieval of data. It performs record processing, CODASYL set processing and structure processing, where a structure is a record aggregate. Structure processing supports IPAD geometry requirements including transformations between IPAD and ANSI representations for geometry. The language interfaces subcomponent provides IPIP user language processing and query processing. The language processors reside on separate system control points and communicate with the data manager through the IPEX communications capability.

#### IPAD Executive, IPEX

IPEX provides a common set of executive services for IPAD software and for application programmers which integrate or interface programs into IPAD. It has two main functional subcomponents, the service routines and the communications facility. The service routines provide functions for data transformations between the IPAD network standard and host formats, gather and reduce performance data to usable form and provide access to fundamental host services like file I/O, terminal I/O, timing, etc. The communications facility provides a host independent software interface to a high level protocol for either intrahost or interhost communications.

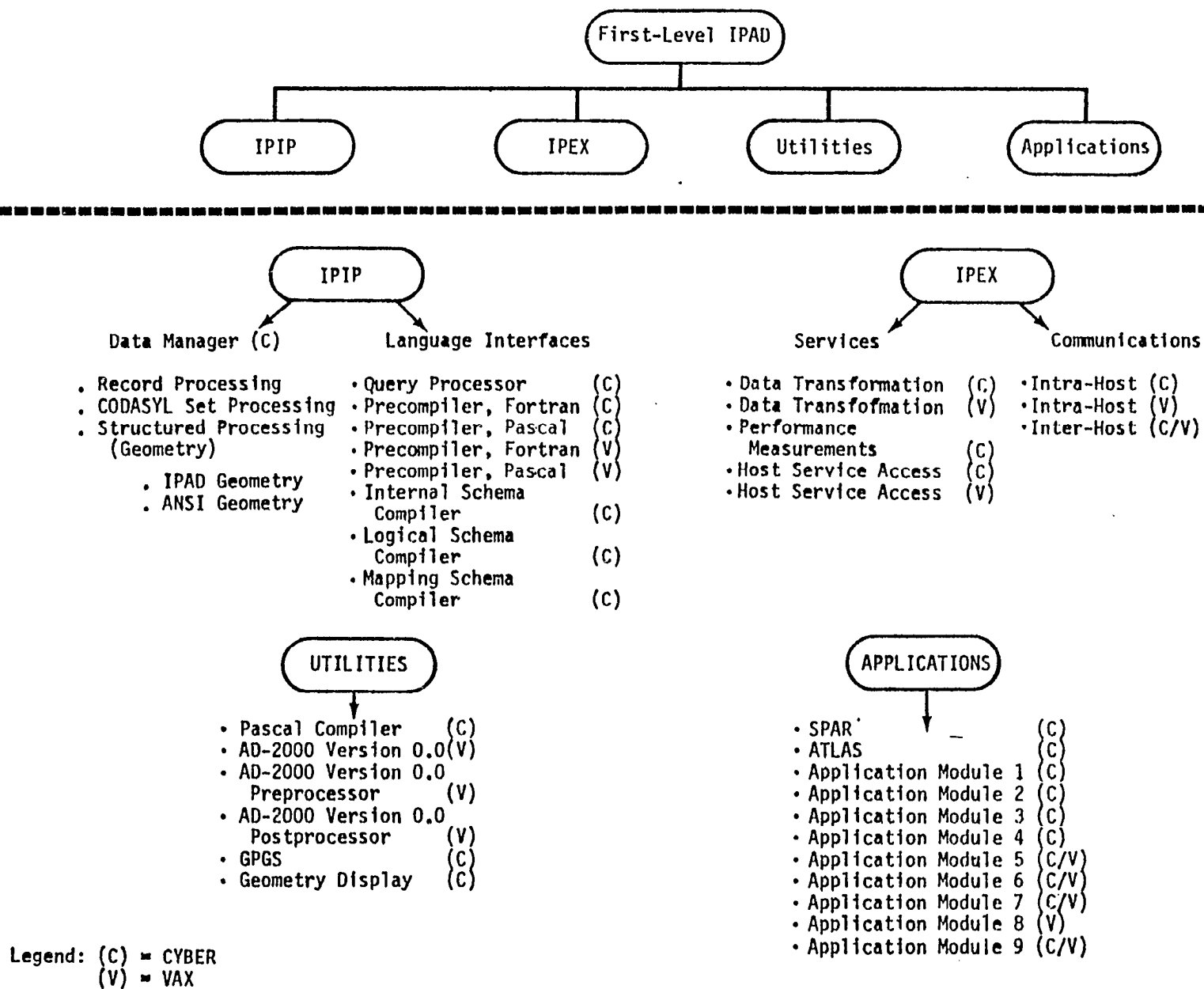


Figure D-1-- FIRST-LEVEL IPAD FUNCTIONAL ARCHITECTURE

## IPAD Utilities

These utilities provide services to application programmers and engineers using IPAD. The Pascai compiler transforms Pascal source programs to executable form. AD-2000 Version 0.0 is an IPAD design/drafting system. AD-2000 Version 0.0 pre- and post-processors interface AD-2000 Version 0.0 with IPIP. GPGS is a device independent graphics routine library which adheres to the ACM SIGGRAPH graphic standard. The geometry display utility provides the IPAD engineering user with a GPGS-based Capability to view geometry stored in IPIP in IPAD standard form.

## Applications

The IPAD applications contain integrated or interfaced user application programs that have been developed, augmented, or modified to support the engineering demonstrations of First-Level IPAD. ATLAS and SPAR are general purpose finite element programs for structural, weights, loads and aerodynamic analyses. The application modules are intended for demonstrations only. They provide the following functions:

Module#	Function
1	Configuration Parameters
2	General Arrangement
3	Project Management
4	Indentured Parts List
5	Manufacturing Geometry
6	Structural Arrangement
7	Structural Analysis
8	Detail Frame Design
9	Data Base Administration

## First-Level IPAD Release 1.0

This release contains the following functional subcomponents:

IPIP Data Manager, Record Processing  
IPEX Service for Data Transformation between CYBER and  
the network standard  
IPEX CYBER Host Service Access as required  
IPEX CYBER Intrahost communications  
CYBER Pascal Compiler  
GPGS

### First-level IPAD, Release 2.0

This release contains all of Release 1.0 and the following functional components:

Data Definition Language Compilers  
CYBER Data Manipulation precompilers  
Application Module 7  
AD-2000, Version 0.0  
ATLAS  
SPAR

### First-Level IPAD, Release 3.0

This release contains all of Release 2.0 and the following functional components:

Query Processor  
IPIP Structure Processing Capability for IPAD Geometry  
Application Modules 3, 4  
VAX Data Manipulation Precompilers  
Interhost Communication  
Performance Measurements  
CODASYL Set Processing Capability in IPIP  
ANSI Geometry Support in IPIP  
Geometry Display Utility  
AD-2000 Version 0.0 Pre- and postprocessor  
Application Modules 1, 2, 5, 6, 8, 9  
VAX Data Transformation Service  
VAX Host Service Access  
VAX Intrahost Communication

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